CHAPTER III.

OFF-ROAD EQUIPMENT

This chapter presents the project criteria for off-road equipment projects under the Carl Moyer Program. It also contains a brief overview of the current emission standards, available control technology, potential incentive projects eligible for funding, and emission reduction calculation and cost-effectiveness calculation methodologies.

A. Introduction

Off-road engines are used in a wide array of applications, including, but not limited to, agricultural tractors, backhoes, excavators, trenchers, and motor graders. Off-road equipment can be further split into two broad categories: less than 175 horsepower and equal to or greater than 175 horsepower. The ARB is preempted from regulating new farm and construction equipment less than 175 horsepower; the USEPA has sole authority to control equipment in this category. ARB has the authority to regulate off-road equipment equal to or greater than 175 horsepower and non-preempted off-road equipment less than 175 horsepower.

Off-road equipment eligible for funding under the Carl Moyer Program includes equipment 50 horsepower or greater. Excluded from this discussion are engines that propel or are used on aircraft, locomotives, and marine vessels. Engines used in locomotive and marine vessel applications are discussed in Chapters IV and V, respectively, and aircraft engines are excluded from the Carl Moyer Program. Also excluded from this discussion are engines used in forklifts and airport ground support equipment. These two off-road categories are discussed separately in Chapters VII and VIII, respectively. This program does not apply to off-road engines used for underground mining operations and are regulated by the Mining Safety and Health Administration.

1. Emission Standards

Emissions from off-road equipment were uncontrolled prior to 1996. Estimates of NOx emission levels from uncontrolled off-road engines range from 8.3 g/bhp-hr to 18 g/bhp-hr. In January 1992, ARB adopted exhaust emission standards for off-road diesel cycle engines 175 horsepower and greater to be effective starting with the 1996 model year engines. Table III-1 lists ARB's existing and future NOx and PM emission standards for off-road diesel cycle engines.

Table III-1
ARB Exhaust Emission Standards for Heavy-Duty Off-Road Engines

Rated Power (horsepower)	NOx and PM Emission Standards (g/bhp-hr)					
	1996		2000		2001	
	NOx	PM	NOx	PM	NOx	PM
175 ≤ hp ≤ 750	6.9	0.4	--	--	5.8	0.16
> 750 hp	--	--	6.9	0.4	--	--

The USEPA has adopted virtually identical NOx emission standards for off-road diesel cycle engines at or above 50 horsepower. The USEPA rule aligns with California's first tier regulations for engines 175 horsepower and greater and took effect in 1996. The USEPA rule also took effect in 1997 for off-road diesel cycle engines at or above 100 horsepower but less than 175 horsepower and in 1998 for off-road diesel cycle engines at or above 50 horsepower but less than 100 horsepower. The combination of ARB and USEPA emission standards means that all of today's new off-road diesel cycle engines 50 to 750 horsepower have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr. Table III-2 lists USEPA's existing and future NOx and PM emission standards for off-road diesel cycle engines.

Table III-2
USEPA Exhaust Emission Standards for Off-Road Diesel Engines

Rated Power (horsepower)	NOx and PM Emission Standards (g/bhp-hr)							
	1996		1997		1998		2000	
	NOx	PM	NOx	PM	NOx	PM	NOx	PM
50 ≤ hp < 100	--	--	--	--	6.9	--	--	--
100 ≤ hp < 175	--	--	6.9	--	--	--	--	--
175 ≤ hp < 750	6.9	0.4	--	--	--	--	--	--
≥ 750 hp	--	--	--	--	--	--	6.9	0.4

USEPA, ARB, and off-road diesel engine manufacturers have signed a Statement of Principles (SOP) that sets forth comprehensive future emission standards for compression ignition (diesel) off-road engines. The SOP provides for new NOx, PM, and carbon monoxide (CO) emission standards for engines with different horsepower ratings to be effective in a tiered approach. The SOP's Tier 1 NOx emission levels for off-road diesel engines 50 horsepower and greater are the same as the ARB's NOx emission standards for off-road diesel cycle engines 175 horsepower or greater, as discussed previously. Starting with model year 2001 engines, the SOP provides for a combined NOx and non-methane hydrocarbon (NMHC) emission levels for off-road engines in this category ranging from 4.8 g/bhp-hr to 5.6 g/bhp-hr (NOx + NMHC). The Tier 2 NOx + NMHC emission levels for off-road diesel engines 50 horsepower and greater will be reduced

further with the incorporation of the Tier 3 emission levels, ranging from 3.0 g/bhp-hr to 3.5 g/bhp-hr NOx + NMHC, starting in 2006. USEPA has adopted regulations for off-road diesel equipment consistent with the emission levels contained in the SOP. The ARB intends to revise California's regulations for off-road equipment to harmonize with federal regulations.

The Carl Moyer Program is intended to provide additional emission reductions immediately by encouraging the purchase of eligible new off-road equipment, or emission-certified off-road engines to replace eligible uncontrolled engines. This program also applies to projects that repower emission-certified equipment with engines certified to an optional NOx emission credit standard. Grants from the Carl Moyer Program can be used for the purchase of eligible retrofit kits that reduce NOx emissions from uncontrolled engines to the 6.9 g/bhp-hr NOx emission standard, or lower. Carl Moyer Program grants can also be used for the purchase of retrofit kits that reduce NOx emissions by at least 15 percent from eligible emission-certified engines.

2. Control Technologies

The purpose of this section is to discuss reduced-emission engines for off-road equipment that are commercially available. The engines discussed are considered suitable as new equipment purchase, or new engine purchase for repower opportunities. Emerging technologies that may be commercially available in two to three years are also discussed. There is no discussion of technologies considered to be in the experimental or pre-prototype category. This section is intended to provide information regarding reduced-emission engine technologies that can be purchased now, and technologies, which have potential to become commercially available in the very near term.

a. Available Technologies

Emission-Certified Engines. Currently, off-road diesel cycle engines 50 horsepower and greater must to comply with a NOx emission standard of 6.9 g/bhp-hr. The NOx emission standard for off-road diesel cycle engines 175 to 750 horsepower sold in California will be reduced to 5.8 g/bhp-hr for the model year 2001 engines. As discussed previously, these standards do not apply to engines used in aircraft, locomotive, or marine vessel applications.

A viable and cost-effective way to reduce emissions from pre-controlled equipment is to replace the engine in that equipment (i.e., repower) with an emission-certified engine instead of rebuilding the existing engine to its original uncontrolled specifications. Although this is commonly a diesel-to-diesel repower, significant NOx and PM benefits may be achievable due to the high emission levels of the uncontrolled engine being replaced. Emission-certified engines are commercially available for off-road engines
50 horsepower and greater that are covered under this program. Off-road equipment comes in a vast array of sizes, weights, and power requirements. Therefore, a particular engine may be suitable for one application but not another. Another option, which may be possible for some situations, is to replace an off-road engine with a new or rebuilt on-road engine certified to a NOx emission standard of 6.9 g/bhp-hr or lower. It may be possible, in some cases, to replace an older uncontrolled diesel engine with a newer emission-certified alternative fuel engine. Even though diesel-to-alternative fuel repower projects for off-road equipment are eligible for funding

under the Carl Moyer Program, they are not expected to be as common as diesel-to-diesel repower projects.

Off-Road Engine Retrofit Technology. Retrofit technology options for off-road diesel engines to reduce NOx emissions from uncontrolled levels to the existing 6.9 g/bhp-hr NOx emission standard, or lower, are limited. Any retrofit technology must be certified for sale in California, must be able to reduce NOx emissions by at least 15 percent, and must comply with established durability and warranty requirements. It is possible that retrofit technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications.

b. Emerging Technologies

Several reduced-emission technologies hold promise for the future, but are not yet commercially available. These technologies are being developed for on-road heavy-duty diesel engines, but they can be used in off-road diesel engine applications as well. Some of these technologies include: aqueous fuel, ceramic coating, and high pressure direct injection natural gas. These technologies may be developed as engine retrofit or new engine technologies, but at the present time, they are not certified for sale in California. Some of these emerging and/or experimental technologies may not be able to be certified during the tenure of this program. These technologies would be ineligible to participate in the Carl Moyer Program since the ARB's policy is to provide funding only for reduced-emission engines or technologies that have been certified. However, for very promising technologies that have sufficiently demonstrated their potential to reduce emissions, ARB could grant, on a case-by-case basis, an experimental permit for an engine with certain technology to operate in California. Experimental permits are

allowed for only one or two engine demonstrations and are granted with very strict limitations. For example, the allowed time for operating equipment with an experimental-permitted engine is usually limited to one or two years, after which the engine has to be removed from service, unless an extension is requested and is justified. The ARB intends experimental permits to be a means to field test a technology in some limited situations and not to be a way to circumvent certification requirements.

B. Project Criteria

The project criteria have been designed to provide districts and equipment operators with a list of minimum qualifications that must be met in order for an off-road equipment project to qualify for funding. The main criteria for selecting a project are: the amount of emission reductions, cost-effectiveness, and ability for the project to be completed within the timeframe of the program. The criteria also establish a method for calculating emission reductions and cost-effectiveness for reduced-NOx off-road equipment projects. Reduced-NOx off-road equipment projects that include equipment repowers or engine retrofits will be considered and evaluated for incentive funding. In general, off-road equipment projects qualifying for evaluation must meet the following criteria:

- For new equipment purchase, the new engine must be certified to an ARB optional NOx emission credit standard for off-road diesel equipment that is at least 30 percent lower than the existing NOx emission standard.

- For equipment repower projects the replacement engine must be certified to a NOx emission standard that is at least 15 percent lower than the current ARB NOx emission standard;

- For engine retrofit projects: (i) the retrofit kit must be certified to reduce NOx emissions to 6.9 g/bhp-hr, or lower, if it is used to retrofit an eligible uncontrolled engine, or (ii) the retrofit kit must be certified to reduce NOx emissions by at least 15 percent if it is used to retrofit eligible emission-certified engines;

- Reduced-emission engines or retrofit kits must be certified for sale in California and must comply with durability and warranty requirements. Qualified engines could include new ARB-certified engines; ARB-certified aftermarket part engine/control devices; or engines with ARB-approved experimental permits;

- NOx reductions obtained through this program must not be required by any existing regulations, memoranda of understanding/agreement, or other legally binding documents;

- Funded projects must operate for a minimum of 5 years and at least 75 percent of equipment hours of operation must occur in California;

- The acceptable maximum project life for calculating benefits from off-road projects is as follows:

	Default without Documentation	Default with Documentation
Off-road New	10 years	15 year
Off-road Repower	7 years	15 years

  A different project life may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

- Projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced.

C. Potential Types of Projects

The primary focus of the Carl Moyer Program is to achieve emission reductions from off-road diesel engines and equipment operating in California as early and as cost-effectively as possible. The project criteria are designed to ensure that the emission reductions expected through the deployment of reduced-emission engines or retrofit technologies under this program are real, quantifiable, and enforceable. A project must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced, and/or subject to a maximum dollar amount to be granted based on the

horsepower ratings of the engine. The project must be operated for at least five years from the time it is first put into operation and at least 75 percent of the hours of operation must occur in California.

1. Purchase of New Emission-Certified Engines

New off-road engines, 50 horsepower or greater, are required to be certified to a NOx emission standard of 6.9 g/bhp-hr. In addition to the 6.9 g/bhp-hr NOx emission standard, the ARB has adopted optional NOx emission credit standards for off-road equipment that start at 5.0 g/bhp-hr and decrease in 0.5 g/bhp-hr increments. Starting in 2001, the NOx emission credit standards for off-road diesel equipment will start at 4.5 g/bhp-hr and also decrease in 0.5 g/bhp-hr increments. The Carl Moyer Program funds the incremental cost of buying new off-road equipment certified to an optional NOx emission credit standard compared to the cost of buying a new off-road equipment certified to the current NOx emission standard. Even though off-road engines certified to an optional NOx emission credit standard are not available now, they may become available during the life of the Carl Moyer Program.

For some off-road equipment (i.e., yard hostlers, yard goats) it may be possible to design the equipment with specifications to power the equipment with a new on-road engine certified to an optional NOx emission credit standard instead of a new off-road equipment engine. Where this is the case, emission benefits from the baseline engine would be calculated based on an on-road engine. If an applicant provides ARB with documentation showing that past practices (the current fleet) is predominantly yard hostlers powered with off-road engines, then an off-road engine emission factor baseline would be used.

2. Repower with Emission-Certified Engines

Purchases of new emission-certified engines to replace uncontrolled engines in existing equipment are expected to be the most common type of project for off-road diesel equipment under this program. Eligible off-road equipment repower projects refers to replacing an older uncontrolled engine with a newer engine certified to either the existing NOx emission standard or to an optional NOx emission credit standard for off-road diesel equipment.

Eligible off-road equipment repower projects also refer to replacing an emission certified engine with a newer engine certified to an optional NOx emission credit standard. Another option, which may be possible for some situations, is to repower off-road diesel equipment with a new or rebuilt on-road engine certified to NOx emission standard of 6.0 g/bhp-hr or lower. In addition, ARB could grant, on a case-by-case basis, an experimental permit for a particular engine with certain technology to operate in California. Funding under the Carl Moyer program is not available to pay for projects where a spark-ignition engine (i.e., natural gas, gasoline, etc.) is replaced with a diesel engine.

Off-road equipment repower projects that replace an existing diesel engine with an eligible reduced-emission diesel engine (either off-road or on-road) are no longer subject to a maximum grant amount awarded, based on the horsepower category of the engine. Based on ARB and district's experience with the first year of the program the grant award caps that were placed on this project category prevented some projects for construction and agricultural equipment from being funded. These project subcategories typically use large equipment with engines that cost above the grant award caps. Funding for off-road repower projects will be based on the cost-effectiveness limit.

The emission factors under section D of this chapter have been revised to account for the new OFFROAD model. The new emission factors may prevent some diesel-to-diesel repower projects from qualifying for funding. Hence the emission reduction requirement for repowers and retrofits, has been modified to 15 percent.

3. Retrofits

Retrofit means making modifications to the engine and/or fuel system such that the retrofitted engine does not have the same specifications as the original engine. Retrofit projects may be applicable to certain off-road diesel engine families. The most straightforward retrofit projects are those that could be accomplished at the time of engine rebuild. This might entail upgrading certain engine and/or fuel system components to result in a lower emission configuration. It is possible that retrofit technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications. To qualify for funding, the engine retrofit kit must be certified to reduce NOx emissions to 6.9 g/bhp-hr, or lower, if it is used to retrofit an eligible uncontrolled engine. The Carl Moyer Program grants will also apply to retrofit kits that reduce NOx emissions from emission-certified engines by at least 15 percent.

Staff revised emission factors under section D of this chapter to account for the new OFFROAD model. The new emission factors may prevent some diesel-to-diesel retrofit projects from qualifying for funding. So the minimum emission reduction requirement for repower and retrofit projects has been modified to allow funding for projects that meet a 15 percent emission reduction requirement.

1. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from off-road diesel equipment operators. A sample application form is included in Appendix D. The applicant must provide at least the following information, as listed in Table III-3.

Table III-3
Minimum Application Information
Off-road Projects

1. Air District:

2. Applicant Demographics
   - Company Name:
   - Business Type:
   - Mailing Address:
   - Location Address:
   - Contact Number:

3. Project Description
   - Project Name:
   - Project Type:
   - Equipment Function:

4. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Annual Hours)

5. VIN or Serial Number:

6. Application: (Repower, Retrofit or New)

7. Percent Operated in California:

8. Annual Diesel Gallons Used:

9. Annual Miles Traveled:

10. Hours of Operation:

11. Project Life (years):

12. Old Engine Information
    - Horsepower Rating:
    - Engine Make:
    - Engine Model:
    - Engine Year:

13. New Engine Information
    - Horsepower Rating:
    - Engine Make:
    - Engine Model:
    - Engine Year:
    - Fuel Type:

14. NOX Emissions Reductions
    - Baseline NOx Emissions Factor (g/bhp-hr):
    - NOx Conversion Factors Used:
    - Reduced NOx Emissions Factor (g/bhp-hr):
    - Estimated Annual NOx Emissions Reductions:
    - Estimated Lifetime NOx Emissions Reductions:

15. Cost ($) of the Base Engine:

16. Cost ($) of Certified LEV Engine:

17. PM Emissions Reductions
    - Baseline PM Emissions Factor (g/bhp-hr):
    - PM Conversion Factors Used:
    - Reduced PM Emissions Factor (g/bhp-hr):
    - Estimated Annual PM Emissions Reductions:
    - Estimated Lifetime PM Emissions Reductions:

18. District Incentive Amount Requested:

D. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

In general, the emission reduction benefit represents the difference in the emission level of a baseline and reduced-emission engine. Emission factors for the baseline engines are listed in Table III-4. These emission factors reflect the recently adopted emissions inventory for off-road large compression-ignited engines, greater than or equal to 25 horsepower. The OFFROAD model incorporated recent data and reflects currently adopted regulations. Engine manufacturers applied some of the technology advancements in the fuel management systems used in 1988 and newer on-road diesel-powered engine to similar off-road engines. The applicant does have the option of testing the uncontrolled engine using an ARB approved test procedure to determine actual emissions. The maximum allowable baseline emissions for pre-1996 engines as determined through in-use testing is 13 g/bhp-hr ($\leq$120 hp) and 11 g/bhp-hr (>120 hp).

Table III-4
Baseline NOx Emission Factors for
Uncontrolled Off-Road Heavy-Duty Diesel Engines (g/bhp-hr)

Model Year	50 –120 hp	120 + hp
Pre - 1988	13	11
1988 – 1996	8.75	8.17

In situations where the model year of the equipment and the model year of the existing engine are different, the model year of the engine will be used to determine the baseline emission factor for emission reduction calculations. For off-road equipment (i.e., yard hostlers, yard goats) designed with specifications to power the equipment with a new on-road engine certified to an optional NOx emission credit standard instead of a new off-road equipment engine, emission benefits from the baseline engine will be based on an on-road engine. If an applicant provides ARB with documentation showing that past practices (the current fleet) is predominantly yard hostlers powered with off-road engines, then an off-road engine emission factor baseline can be used. The emission level is calculated by multiplying an emission factor, a conversion factor and an activity level. Because the conversion factor and the activity level could be different for the baseline and reduced emission engine, the emission level should be calculated first and then the difference taken to determine the emission reduction. The examples in the February 1999 Carl Moyer Program Guidelines, where the emission reductions were simply based on the difference in emission factors, assumed that there was no change in the conversion factor or activity level. For off-road equipment, the activity level is either the annual hours of operation or fuel consumed. Emission reduction calculations would be consistent with the type of records that would be maintained over the life of the project.

If the annual hours of operation are the basis for determining the emission reductions, the conversion factor is the horsepower of the engine multiplied by the load factor of the application and the activity level should be based on the actual hours of the equipment. The load factor is an indication of the amount of work done, on average, by an engine for a particular application, given as a fraction of the rated horsepower of the engine. The load factor is different for each application. If the actual load factor is known for an engine application, it should be used in

calculating the emission reductions. If the load factor is not known, the proposed default values provided below should be used. Another variable in determining the emission reductions is the number of hours that the equipment operates a year. If the equipment is not outfitted with an hour meter then the hours of operation may not be used for calculating emission reductions. The hour meter is the required instrument for the applicant to use when providing a district with estimated annual hours of operation. The adopted OFFROAD emission inventory model reflects load factors from 0.43 to 0.78 for both heavy-duty diesel engines in agricultural and construction applications. The default load factor for off-road equipment in agricultural and construction applications is:

Default Load factor for
Agricultural and Construction Equipment: 0.43

If the annual fuel consumption is used, an energy consumption factor should be calculated and the activity level should be based on actual annual fuel receipts or other documentation. The energy consumption factor converts the emission factor in terms of g/bhp-hr to g/gallon of fuel used. There are two ways of calculating the energy consumption factor: 1) by dividing the horsepower of the engine by the fuel economy in units of gallons/hour or 2) by dividing the density of the fuel by the brake-specific fuel consumption of the engine. While actual fuel receipts support the annual fuel consumption of the baseline engine, the annual fuel consumption of the reduced-emission engine is an estimate proportion to the change in the energy fuel consumption factor. For example, a reduced-emission engine having an energy consumption factor of 20, replacing a baseline engine which uses 3,696 gallons/year and has an energy consumption factor of 18.5, would have an estimated annual fuel consumption of 3,419 gallons/year. Future fuel receipts or equivalent documentation should be submitted, throughout the project life, as verification of this estimate.

2. Cost-Effectiveness Calculation

The portion of the cost for a repower project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing and installing the new, emission-certified engine and the total cost of either rebuilding the existing engine or the cost of buying a "conventional" replacement engine.

Only the amount of money provided by the Carl Moyer program and any local district match funds can be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, when multiplied with the initial capital cost, gives the annual cost of a project over its expected lifetime.

$$\textbf{Capital Recovery Factor (CRF)} = [(1 + i)^n (i)] / [(1 + i)^n - 1]$$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for off-road equipment projects are provided below.

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a particular off-road equipment project, two examples are presented below. The first example describes the calculations based on hours of operation, whereas, the second example describes the calculations based on fuel consumption.

Example 1 – Construction Equipment Repower (Calculations Based on Hours of Operation). An equipment owner applies for a Carl Moyer Program grant for the purchase of a new off-road diesel engine rated at 180 hp to replace a 1985 uncontrolled diesel engine rated at 150 hp used in a construction loader. The owner does not know the load factor for this application. Both the old and new engine will operate 700 hours annually and 100 percent of the time in California. The cost of the new emission-certified diesel engine is $13,400 whereas the cost to rebuild the old engine would be $8,000. Installation and re-engineering cost (to install the new engine into the existing equipment) is $3,000.

Emission Reduction Calculation

Baseline NOx Emission Factor:	11 g/bhp-hr
Reduced NOx Emission Factor:	6.9 g/bhp-hr
Baseline Horsepower:	150 hp
Reduced Horsepower:	180 hp
Baseline Load Factor:	0.43
Reduced Load Factor:	0.36
Annual Hours of Operation:	700 hours
% Operated in CA:	100%

Hence, the estimated reductions are:
[(11 g/bhp-hr * 0.43 * 150 hp) – (6.9 g/bhp-hr * 0.36 * 180 hp)] * 700 hrs/year * 100% * ton/907,200 g = **0.20 tons/year NOx emissions reduced**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (7 years default life), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total installed cost of new engine:	$ 13,400 + $ 3,000 = $ 16,400
Incremental Capital Cost:	$ 16,400 - $ 8,000 = $ 8,400
Max. Amount Funded:	$ 8,400

Capital Recovery:	$[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost:	(0.17)($ 8,400) = $ 1,428/year
Cost-Effectiveness:	($ 1,428/year)/(0.20 tons/year) **= $ 7,140/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced and would qualify to receive the entire incremental cost ($8,400).

Example 2 – Agricultural Harvester Repower (Based on Fuel Consumption). An equipment owner applies for a Carl Moyer Program grant for the purchase of a new off-road diesel engine (2000, 170 hp, 6.9 g/bhp-hr NOx) to replace an uncontrolled diesel engine (1980, 200 hp, 11 g/bhp-hr NOx) used in a harvester. The installed cost of the new emission-certified diesel engine is $9,500, whereas, the cost to rebuild and install the old engine would be $6,900. The new engine will use 4,600 gallons of diesel fuel annually and will operate 100 percent of the time in California.

Emission Reduction Calculation

Baseline NOx Emissions:	11.0 g/bhp-hr
Baseline Energy Consumption Factor:	18.5 hp-hr/gal
Baseline Annual Fuel Consumed:	4,600 gallons
Reduced NOx Emissions:	6.9 g/bhp-hr
Reduced Energy Consumption Factor:	21.8 hp-hr/gal
Reduced Annual Fuel Consumed:	3,904 gallons
% Operated in CA:	100%
(ton/907,200 g):	Converts grams to tons

Hence, estimated annual NOx reductions are:
[(11.0 g/bhp-hr * 18.5 bhp-hr/gal * 4,600 gal/yr) – (6.9 g/bhp-hr * 21.8 hp-hr/gal * 3,904 gal/yr)] * 1.0 * ton/907,200 g = **0.38 tons/year**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost:	$ 9,500 - $ 6,900 = $ 2,600
Max. Amount funded from Carl Moyer Program:	$ 2,600
Capital Recovery:	$[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost:	(0.23)($ 2,600) = $ 598/year
Cost-Effectiveness:	($ 598/year)/(0.38 tons/year) **= $ 1,574/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced and would qualify to receive the entire incremental cost ($2,600).

B. Reporting and Monitoring

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new engine purchases or for equipment repowering or engine retrofit projects. This is to ensure that the equipment is operated as stated in the program application. Off-road diesel equipment operators participating in the Carl Moyer Program are required to keep appropriate records during the life of the project funded. Records must contain, at a minimum, total hours operated or amount of fuel used, and maintenance and repair information. Records must be retained and updated throughout the project life and made available at the request of the district.